Available online at www.sciencedirect.com

SciVerse ScienceDirect

IERI Procedia 3 (2012) 73 – 80

Procedia IERI

www.elsevier.com/locate/procedia

2012 International Conference on Mechanical and Electronics Engineering

Design of a DC Linear Power Supply with Adjustable Voltage

Guo Jian[a,*], Zhu Jie[a], Zhou Li[a]

[a]*Information School, Beijing Wuzi University, Fuhe No.1,Tongzhou District,Beijing 101149, China*

Abstract

Because of the advantages of high stability, small ripple, linear power supply is suitable to high stability requirements fields. The working principle and deficiencies of the existing DC linear power supply is analyzed. And the implementation of a new linear power supply with tunable voltages is put forward. In the premise of no change of the output voltage circuit feedback dynamic performance, output voltage can be adjustable. The power has the characteristics of over-current protection for output and lower error caused by temperature drift, time drift, component parameter tolerance and lower cost, higher output resolution, etc.

Keywords: tunable voltage; linear power supply; resolution; over-current protection

1.Introduction

DC power supply is an integral part of the various types of electronic equipment. DC power supply is usually divided into a DC linear power supplies and DC switching power supply. DC linear power supply is the earliest and most widely used kind of power [1]. It reduces the voltage amplitude of alternating current through the transformer, and then through the rectifier circuit rectified, pulsed DC, the DC voltage with small ripple voltage filtering is obtained [2]. To achieve high-precision DC voltage, regulator must be done through the circuit. Linear power with lower production costs can achieve high stability and very small ripple, and

*Corresponding author. Tel.: +86-10-89534051, +8618911530698.
E-mail address: guojian760118@163.com.

 doi:10.1016/j.ieri.2012.09.013

there is no interference and noise of the switching power supply, but its efficiency is relative low [3]. Switching power supply has the characteristics of high efficiency, small size and a wide range of input voltage, but it is less stable than linear power [1, 4-5]. Therefore, linear power supply is still the preferred in the high stability requirements fields [6]. At present, the linear power supply is still widely used in scientific research, the field of electrical, electronic circuit, electroplating, broadcast television transmission, communications, college universities, laboratories and other essential equipment by the electronic circuit [7-8].

2. The working principle and deficiencies of the existing DC linear power supply

The linear DC power supply is obtained through a series transistor between the input and output. The transistor which works in the linear region of the voltage - current characteristic curve plays the role of variable resistor.

2.1. The working principle of the existing DC linear power supply

Fig.1 shows the working principle diagram of a conventional linear power supply. The negative input of the error amplifier is connected to the reference source of the error amplifier, and the positive input is connected to the output feedback which is got from output voltage through R1 and R2 voltage divider. Actually, the positive and negative input voltages of the ideal op-amp are equal, which is ensured by changing the output. Therefore, in the case of steady-state, the voltage of the node connecting R1 and R2 can be considered (almost) equal to VREF. Assume that there is no current outflow or inflow in the op amp input, then, by Ohm's law, the formula $R2/(R1+R2)=V_{REF}/V_{OUT}$ is obtained. So, the output voltage is $V_{OUT}=V_{REF}*(1+R1/R2)$.

When applied to the power control loop theory, we are only concerned about the change (or disturbance), and not pay attention to direct traffic. If the error amplifier is the common voltage feedback op amps, and lower sub-pressure resistance R2 is only a DC bias resistor and it has no (direct) roles in analyzing AC loop.

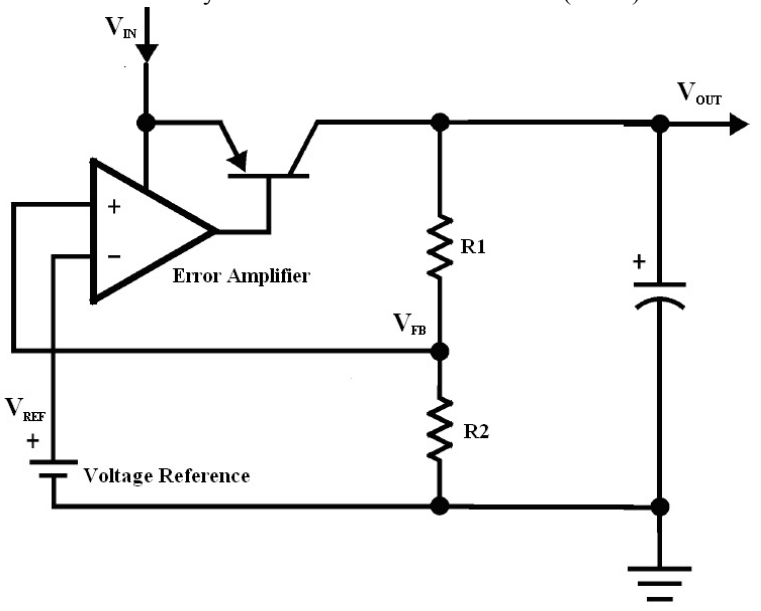

Fig.1. A linear regulator power supply schematic diagram

2.2. the deficiencies of the existing DC linear power supply

Multi-ring mechanical potentiometers are used for the adjustment of output voltage in the ordinary adjustable DC power supply. Mechanical potentiometers have shortcomings of mechanical wear and are afraid of vibration, easily damaged when frequent moves. When it is used to adjust DC power supply voltage, there are other shortcomings, such as regulator difficulties, low accuracy of adjustment, poor consistency and so on. With the development of electronic technology, the digital potentiometer is instead of the multi-turn potentiometer. Fig.2 is an application of a digital potentiometer or mechanical potentiometer (variable resistor R2) adjustable linear regulator power supply schematic. But the output resolution of the digital potentiometer is low, and generally, it is less than 10, and the adjustment accuracy can not reach a high level.

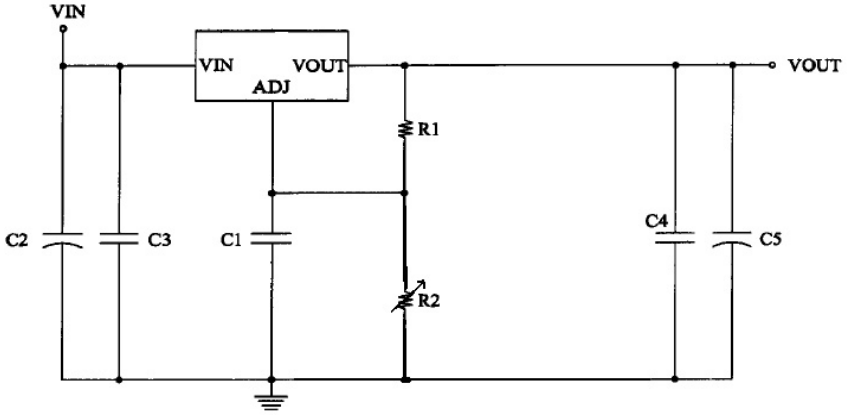

Fig.2. the principle diagram of a linear power with adjustable voltage

3. The Working principle of the new linear voltage adjustable DC power supply

An adjustable output voltage is obtained by introducing a resistor R3 in the node R1 and R2 and the set voltage V_{SET}, which is shown in Fig. 3.

From above, we know that V_{FB} is equal to V_{REF}. So, the relationship of V_{OUT}、 V_{FB} and V_{SET} is shown as following.

$$V_{FB} = \frac{R2 // R3}{R1 + R2 // R3} * V_{OUT} + \frac{R1 // R2}{R3 + R1 // R2} V_{SET} \quad (1)$$

Here, Rx//Ry is resistance value of two resistors in parallel. So,

$$V_{FB} = \frac{R2*R3/(R2+R3)}{R1+R2*R3/(R2+R3)} * V_{OUT} + \frac{R1*R2/(R1+R2)}{R3+R1*R2/(R1+R1)} * V_{SET}$$

$$\Rightarrow V_{OUT} = (1 + \frac{R1}{R2//R3}) * V_{FB} - \frac{R1}{R3} * V_{SET}$$

Since $V_{FB}=V_{REF}$,

$$V_{OUT} = (1 + \frac{R1}{R2 // R3}) * V_{REF} - \frac{R1}{R3} * V_{SET} \quad (2)$$

is obtained.

From formula(2), V_{SET} and V_{OUT} has a inversely proportional to the linear relationship, so, by setting different given voltage, different output voltage can be got, which realized the output voltage regulation.

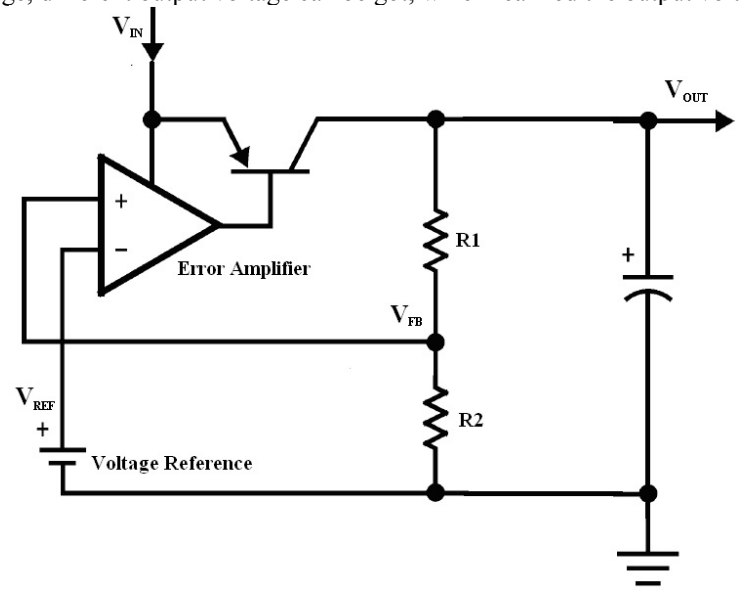

Fig.3. Diagram of setting voltage

4. Design of a new voltage adjustable DC linear power supply

The linear power supply system includes several major portion of the auxiliary power system, the system main circuit, the system microcontroller circuit and so on.

4.1. The Auxiliary Power Supply

The auxiliary power supply system is shown as Fig.4. +20V is taken as an example in this paper.

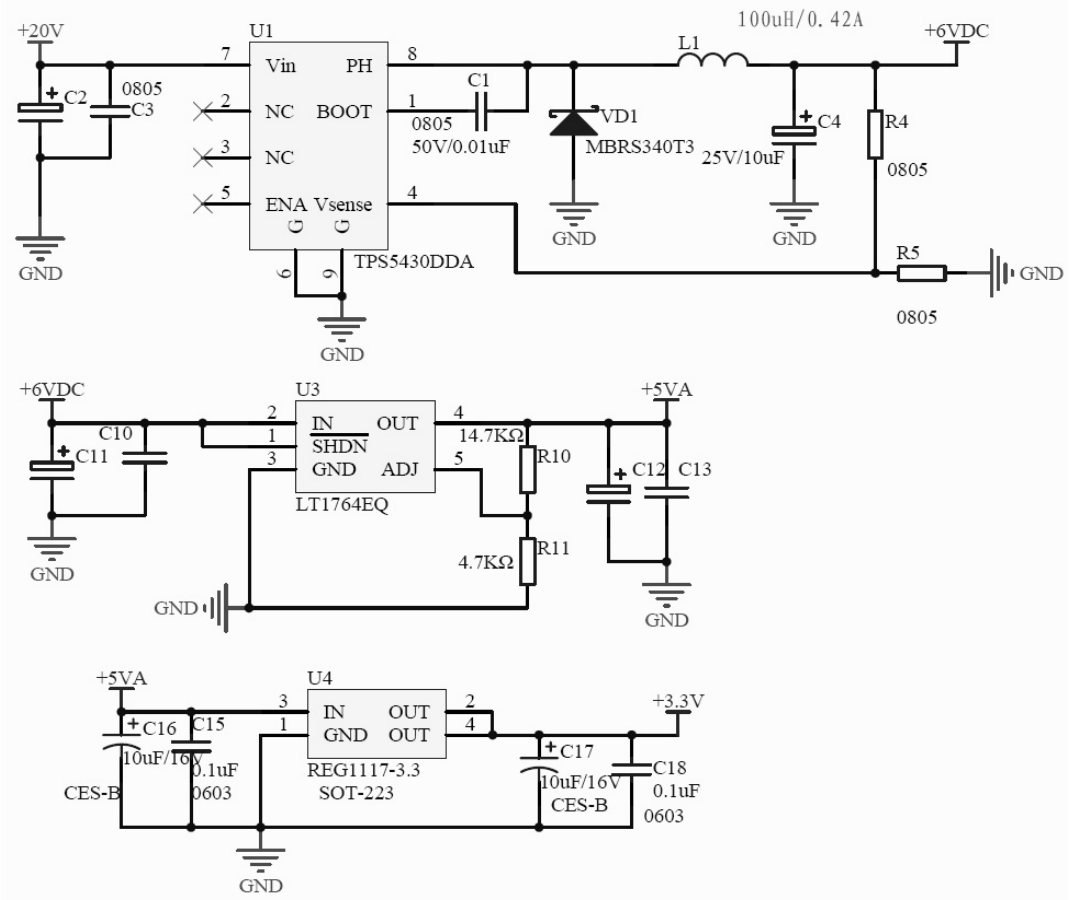

Fig.4 The Auxiliary power supply

The system is a power supply circuit which consists of an integrated DCDC conversion chip TPS5430 and the external inductance, resistance and capacitance, and diode. It can convert +24 V DC voltage into a +6 VDC. The +5VA power supply is obtained from the linear power chip LT1764EQ and +3.3V power supply is got from the chip REG1117-3.3 and their respective circuit components. The +3.3 V and +5 VA provide supply for the system microcontroller, digital interface and OPA2350 op-amp and voltage reference respectively.

4.2. The System Main Circuit

The system main circuit is shown in Fig.5.

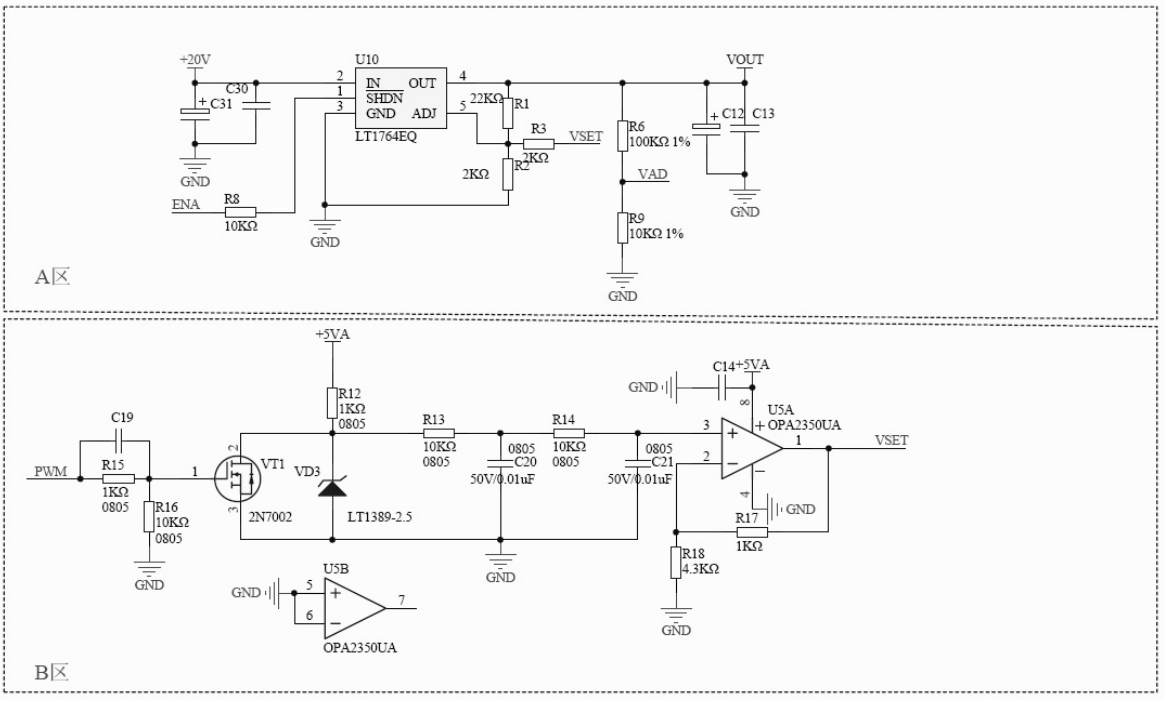

Fig. 5 The system main circuit

The main circuit of the system is used to achieve adjustable output voltage. Area A in Fig.5 is power conversion circuit section and B area circuit is adopted to generate the set voltage in the V_{SET}.

In the A area in Fig.5, U10 (LT1764EQ), C12, C13, R1, R2 and R3 form a linear voltage conversion circuit. pin 5 of U10 is clamped to 1.21V when working. When R1, R2 and R3 values are put into the formula (3), the voltage output(Unit V) in Fig.5 is shown as following.

$$V_{OUT}=27.83-11*V_{SET} \quad (3)$$

From formula(3), when V_{SET} is less than 0.718V, the V_{OUT} gets the maximum. That is, when the input voltage is 20V, V_{SET} is larger than 0.718V, V_{OUT} is deceased linearly with the V_{SET} increase and the scale factor is -11. C30 and C31 input capacitor. R6 and R9 form the output voltage sampling network, single-chip output voltage signal is sampled by the on-chip 12-bit ADC to monitor the output voltage and if necessary, it will adjust the output voltage.

Fig.5 B zone is a circuit containing two-order RC filter pulse width modulated signal to analog signal. PWM wave from microcontroller output drive MOS transistor VT1 and make the VT1 work in the switch state. When the on-resistance of VT1 is ignored, the leakage point is 0V when conducting and is 2.5V when it is off. So, the input of the 2nd order RC low-pass filter is 2.5V pulse width modulation signal which is filtered and the direct flow is enlarged by OPA2350 and then is sent to R3 as a setting voltage.

4.3. The System Microcontroller Circuit

The system microcontroller circuit is shown in Fig. 6.

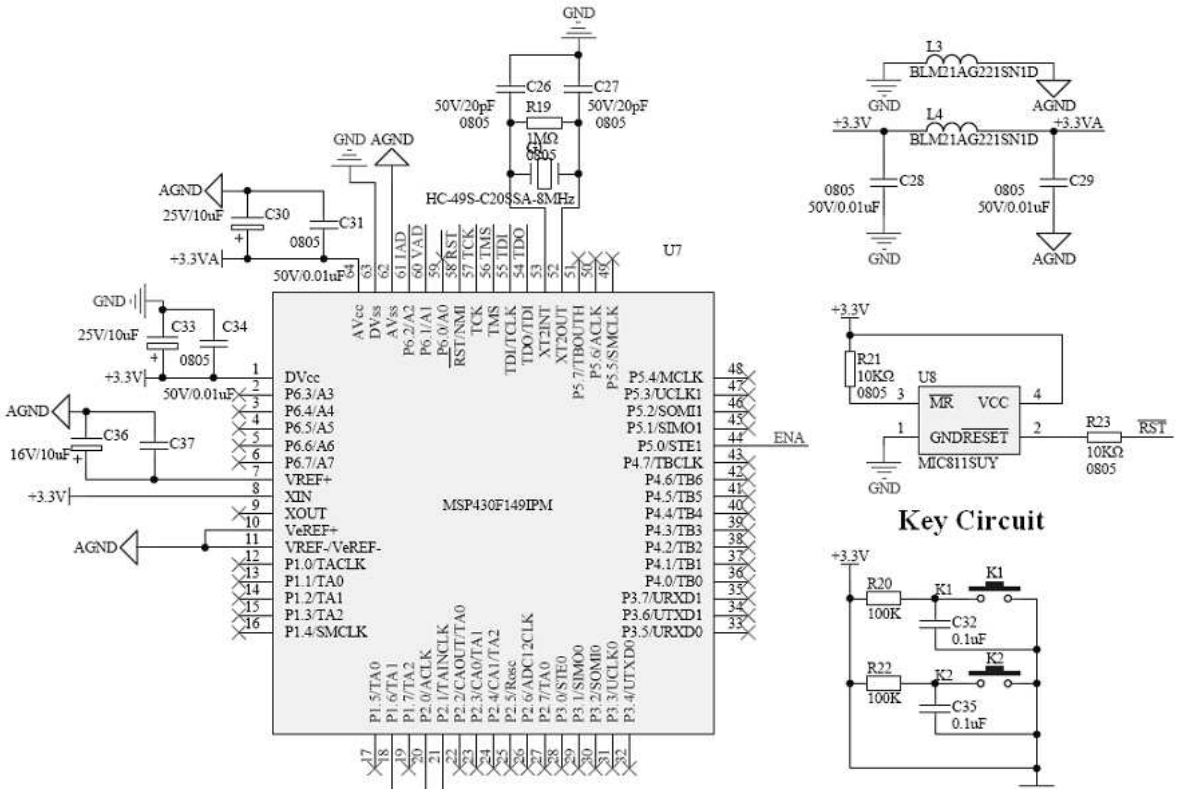

Fig.6. The microcontroller circuit of system

The Microcontroller U7 is used to achieve a sampling of the output current and voltage with its own integrated 12-bit ADC. Pin 61 is the input of output current signal and pin 60 is the input of the output voltage signal. When the output current which exceeds the set value is detected by the microcontroller, by prohibiting U2 and shutdown the output voltage, overcurrent protection can be carried out. Microcontroller is also used to detect the output voltage. Once the output deviates from the output settings, which is due to time or temperature drift of system and the discrete of components parameters, the output voltage can be regulated, therefore, the temperature drift, time drift and components parameter tolerance of the system can be reduced. The pin 44 output to enable signal pin 1of U10 (LT1764EQ) (through R8), and only when pin 44 output is high, the U10 can work and output voltage adjustable. The K1of keyboard circuit is connected to the U7's pin 20, K2 is connected to the U7's pin 21. After power-up, a default value is output and when K1 key is pressed, the output voltage is increased and when K2 is pressed, the output voltage is decreased.

5. Conclusions

Due to production of low cost, high stability, small ripple, low interference and noise characteristics, the linear power supply are widely used in scientific research, power electronics, electroplating, broadcast television transmission, communications areas. The principle and deficiencies of the traditional linear power supply are analyzed and a new type linear power supply with voltage adjustable is designed and implemented. Through the improvement of the feedback circuit, in the premise of no changing the dynamic performance of

power conversion circuit feedback, the output voltage can be adjusted. By sampling the output voltage signal, power drift, time drift, and the output error caused by component parameters tolerance are reduced. At the same time, the voltage set is obtained by the PWM signal converted to analog signals, which can effectively reduce system costs and achieve a higher output voltage resolution

Acknowledgements

The paper is supported by the Funding Project for Research base - innovation platform - modern logistics information and control technology（PXM2012014214000067）and for Academic Human Resources Development in Institutions of Higher Learning Under the Jurisdiction of Beijing Municipality (PHR201007145, PHR201108311), and Funding project for Beijing excellent talents (2010D005009000002).

References

[1]ZHANG Gaochao, JI Zhenshan. Design of High- performance Regulated D. C. Power Supply[J]. Journal of zhengzhou textile institute, 1996,(7)3: 40-42
[2]LV Tianwen. China Linear and switching power supply situation and development trend analysis[J]. The World of Power Supply, 2011.2:8-9.
[3]LI Xiangli, QI Hanhong, WEI Yanjun, MA Yan. Switch linearity hybrid power supply based on single chip microcomputer[J]. Manufacturing Automation, 2011,33(5):111-113
[4]SHI Ying, ZHOU Luowei, XIE Pin-fang. Hybrid Power Supply Based on One Cycle Control[J]. Journa l of Chongqing University(Natural Science Edition), 2006,29(9): 44-47
[5]LIU Chenxi, ZHAO Lihua, BAI Sanzhong. A fusion of the advantages of switching power supplies and linear power DC / DC converter[J]. Electrical Manufacturing, 2008(11):52-54.
[6]HU Wenhua. The Research on Switch Linearity Hybrid Power Converter[J]. Journal of East China Jiaotong University, 2007(4):67-70.
[7]Wang Yunye, Yu Shuibao, Song Jun. Design of high stability and low ripple power supply [J]. Microcomputer & Its Applications, 2011, 30(19):22-24
[8]QIN Yangyang, YE Yan. How to design the NC power of the linear regulator[J]. Science & Technology Association Forum, 2009(9):32-33.